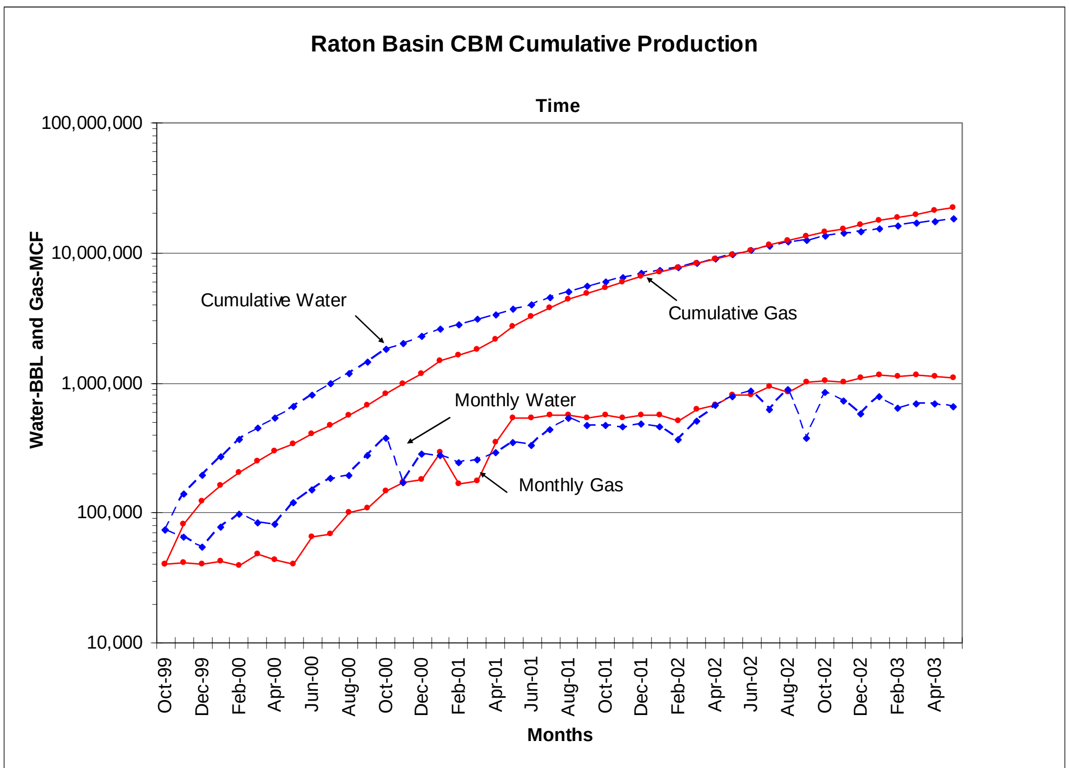
Chapter 5 Production Analysis and Estimation

5.1 General characteristics

The objectives of this chapter are to address the following key points: (1) to analyze current well performance and determine the estimated ultimate recovery (EUR) and other production characteristics of the Raton Basin play, and (2) to identify any interference in the production response between wells and thus qualitatively determine drainage area.

Cumulative gas and water production to May 2003 from the New Mexico portion of the Raton Basin was 22.1 Bscf (billion standard cubic feet) of gas and 18 million barrels of water, respectively. Figure 5.1 illustrates the trend in development since the date of first production in October 1999.



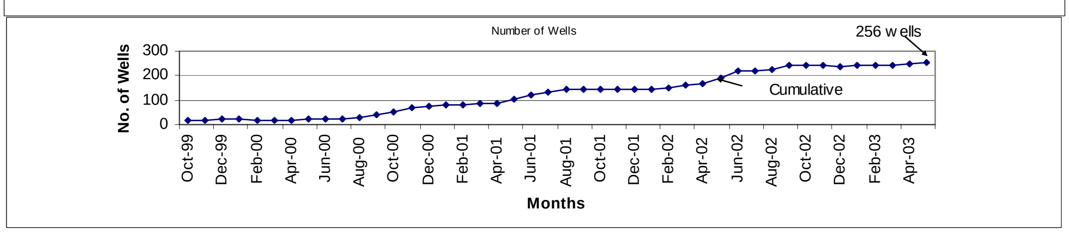


Figure 5.1 Cumulative and monthly gas and water production from all wells in the New Mexico portion of the Raton Basin, with active wells shown at the bottom. Individual well data production is available in the Oil and Gas Well Database on the accompanying CD-ROM.

It is evident from the increasing number of wells that this pool is currently undergoing active development. In response to the additional wells, monthly production has increased until mid-2002 at which time production has remained constant. Latest monthly production rates (May 2003) are 1.1 Bscf/month and 660,000 barrels of water/month from approximately 260 producing wells.

The production from the Raton Basin in New Mexico can be divided two areas as shown in Figure 5.2. These individual areas of development are defined by geological and/or surface restrictions. Individual production plots for each lease (A, E, C, in northeast area and B, D in southwest area) are shown in Figures 5.3 through 5.7, respectively. Each figure includes cumulative and monthly production for gas and water and the active number of wells on a monthly basis.

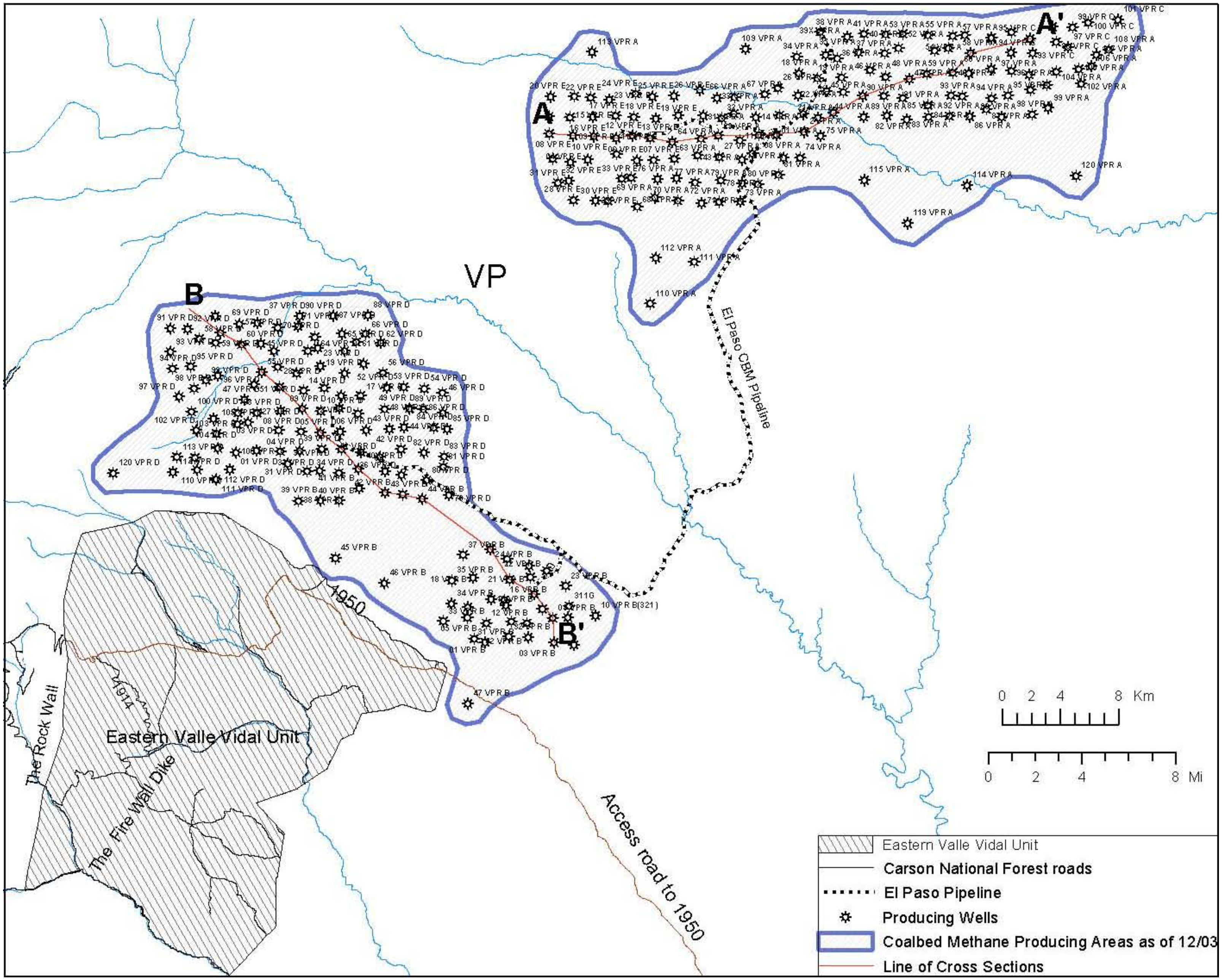


Figure 5.2 Location map identifying the areas of coalbed methane development northeast and southwest of Vermejo Park (producing wells on this map are current through 2003).

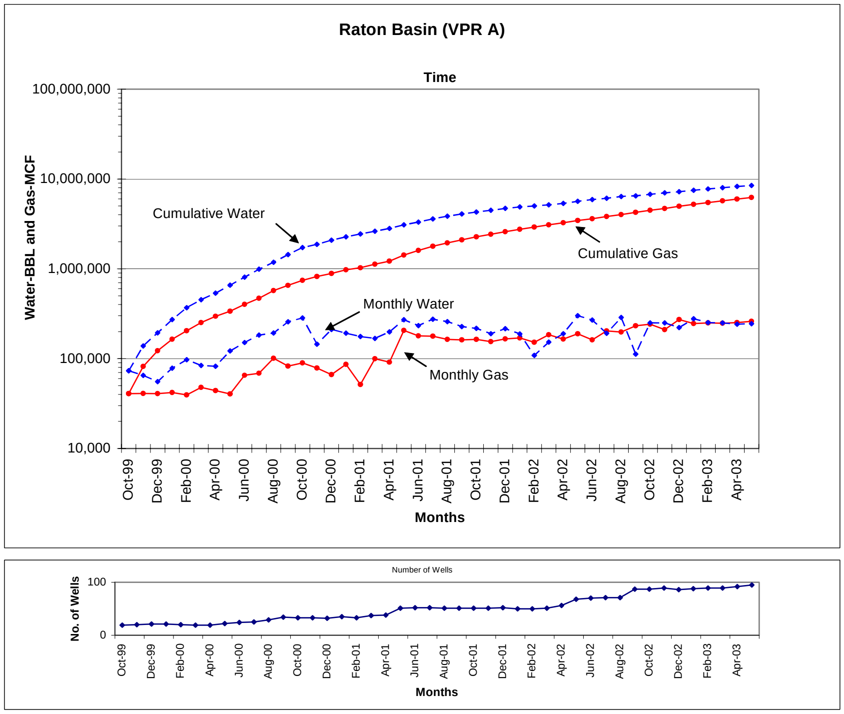
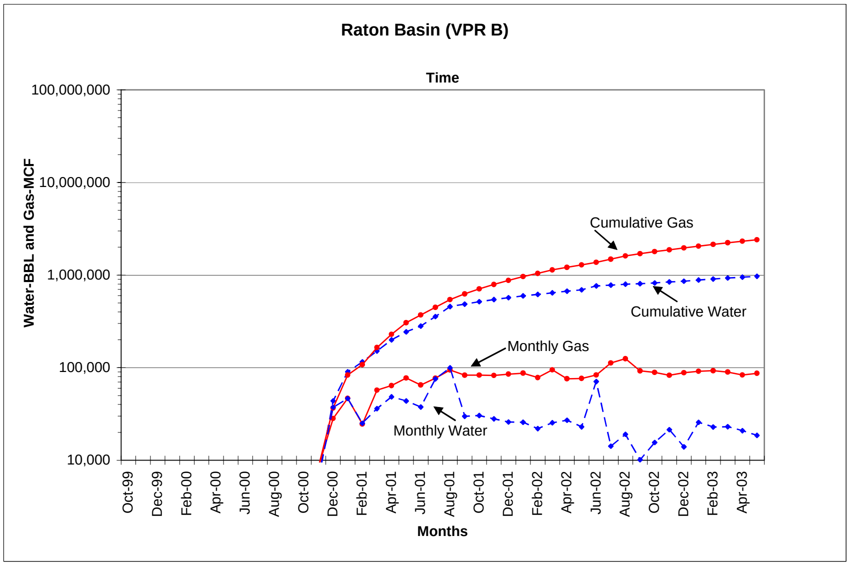


Figure 5.3 Cumulative and monthly gas and water production for **VPR** (Vermejo Park Ranch) **A wells** (central part of northeast producing area, refer to Fig. 5.2 for location) in the New Mexico portion of the Raton Basin, with active wells shown at the bottom.



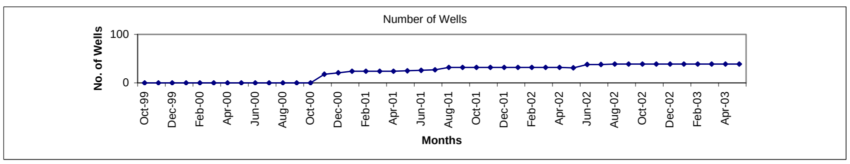


Figure 5.4 Cumulative and monthly gas and water production for **VPR B wells** (eastern part of southeast producing area, refer to Fig. 5.2 for location) in the New Mexico portion of the Raton Basin, with active wells shown at the bottom.

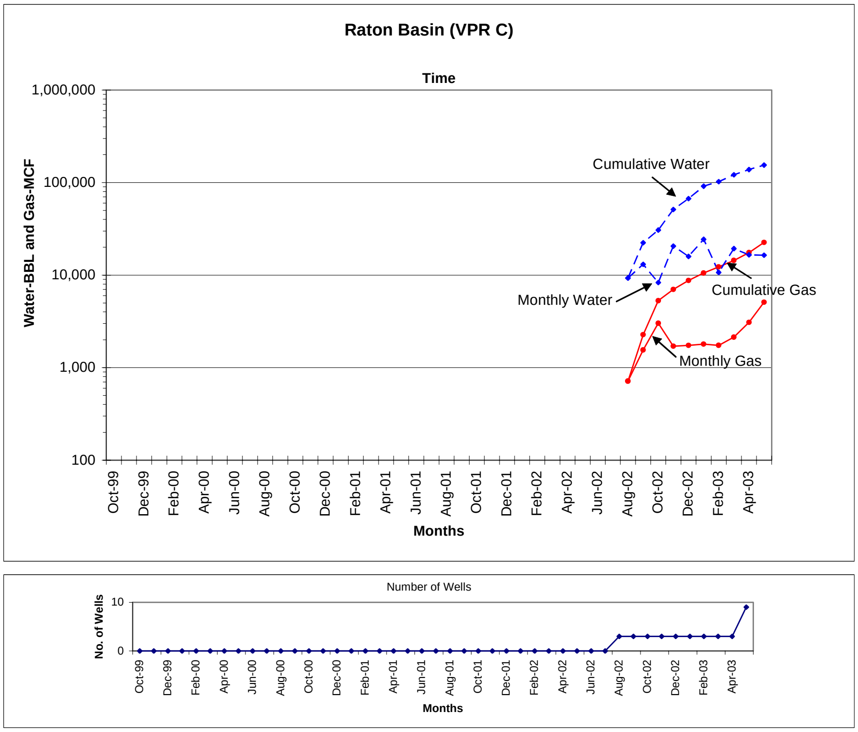


Figure 5.5 Cumulative and monthly gas and water production for **VPR C wells** (eastern end of northeast producing area, refer to Fig. 5.2 for location) in the New Mexico portion of the Raton Basin, with active wells shown at the bottom.

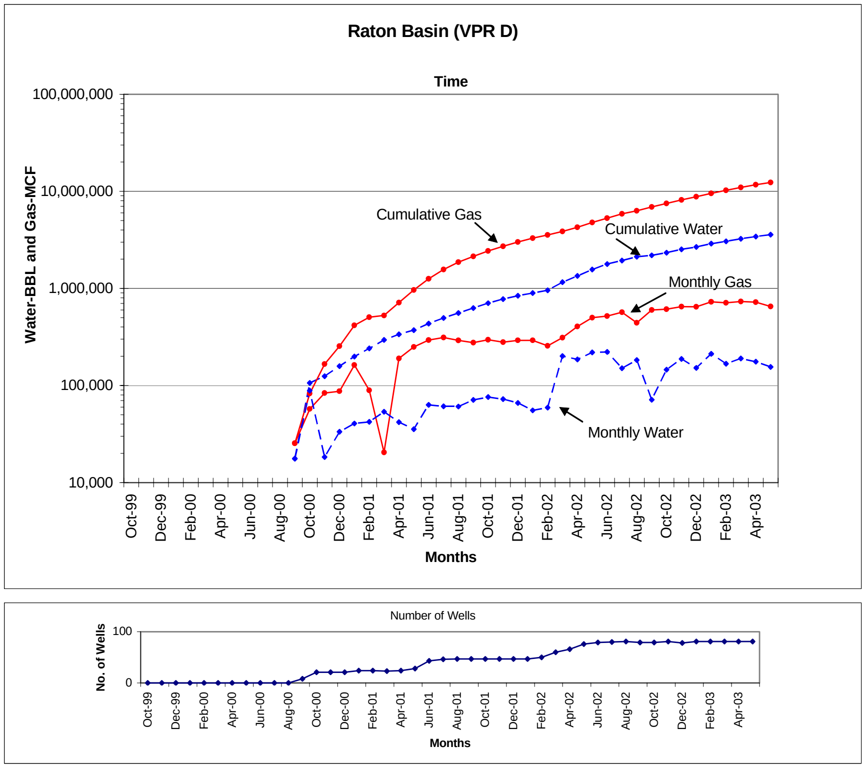
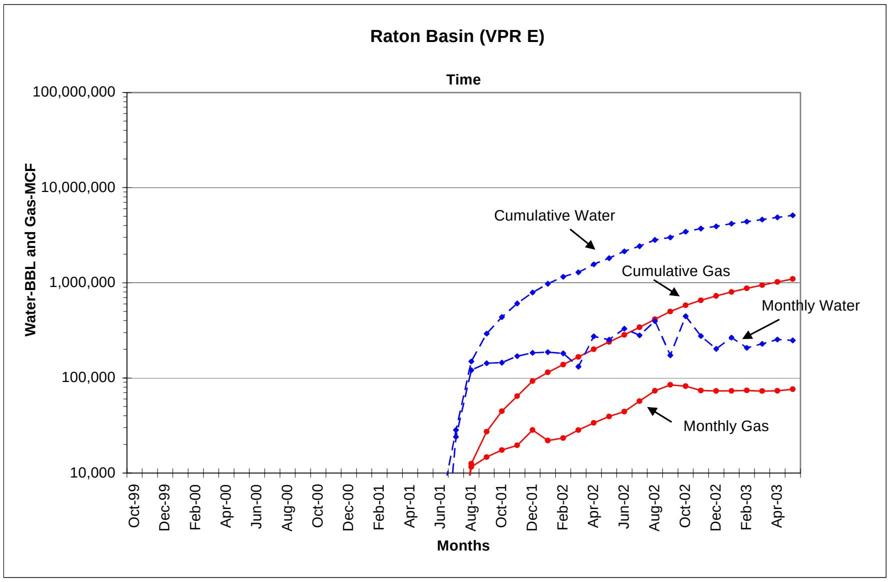


Figure 5.6 Cumulative and monthly gas and water production for **VPR D wells** (western part of the southeast producing area, see Fig. 5.2 for location) in the New Mexico portion of the Raton Basin, with active wells shown at the bottom.



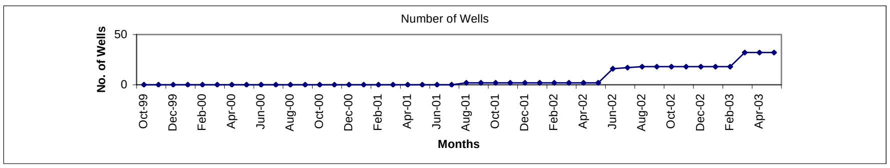


Figure 5.7 Cumulative and monthly gas and water production for **VPR E wells** (western part of the northeastern producing area, refer to Fig. 5.2 for location) in the New Mexico portion of the Raton Basin, with active wells shown at the bottom.

A comparison of production statistics by region is shown in Table 5.1. The most prolific group of wells is in VPR D, where 56% of the cumulative gas production has occurred as of May 2003. VPR A, which has the highest percentage of wellbores (37%), has the distinction of producing the highest cumulative water at 46%. In fact, regions A, C, and E have significantly greater cumulative water-gas-ratios (WGR) than regions B and D.

Lease	Date of 1st production	No. of wells	Gp mmscf	Wp mBw	Gp/well mmscf	Wp/well mBw	WGR
A	Oct 1999	**95**	6,227	**8,490**	66	89	1.36
B	Nov 2000	39	2,405	969	62	25	0.40
C	Aug 2002	9	23	154	3	17	6.81
D	Sep 2000	81	**12,351**	3,576	**152**	44	0.29
E	Jul 2001	32	1,096	5,116	34	**160**	4.67
	total	256	22,102	18,305			

Table 5.1 Production characteristics for Raton Basin

5.2 Analysis of single well performance

The Vermejo Formation producing interval consists of a series of thin coal seams interbedded with sandstone beds. Subsequently, without individual zone tests, it is only possible to determine production for a well with any accuracy, and not for a formation or a zone. Furthermore production from many wells is commingled with the shallower Raton Formation. Table 5.2 provides production statistics for the Vermejo-only completions and compares the results to the total Raton Basin play.

Lease	No. of Vermejo-only wells	% of total in region	Average net perforated thickness Ft	Gp mmscf (Vermejo only)	% of total in region	Wp mBw (Vermejo only)	% of total Vermejo-only in region
A	22	23	19	1,605	26	3,569	42
B	30	77	33	2,123	**88**	875	90
C	0	0	0	0	0	0	0
D	68	84	26	11,546	**93**	3,123	87
E	1	3	14	48	4	311	6
total	121	47	26	15,322	69	7,878	43

Table 5.2 Production statistics for Vermejo Formation-only completions (excludes wells where Raton Formation production is commingled with Vermejo Formation production). There are no Vermejo-only wells in the C Lease. Gp = gas production, Wp = water production, mmscf = million standard cubic feet of gas, mBw = thousand barrels of water.

A total of 121 wells are completed only in the Vermejo Formation, or 47% of the total completions to May 2003. These wells contribute 69% of the cumulative gas production and 43% of the cumulative water production, respectively. Investigating production from individual leases reveals that a majority of the gas production from VPR B and D is from the Vermejo Formation, 88 and 93%, respectively. Furthermore, a majority of water production is from the Raton Formation in VPR A and E, respectively.

A major challenge in evaluating production is to distinguish the unconventional coalbed methane response from the conventional gas sand response. Examining the production curves for the existing wells resulted in identifying four scenarios as shown in Figure 5.8. Type I exhibits the classic coalbed methane response; i.e., brief, initial high water production followed by a normal decline and initial low gas production which steadily increases to a peak after some period of time, followed by normal decline behavior. In Type II, the volume of water production is low with a small to non-existent decline, while the gas inclines and remains at a stable value (no decline observed). Type III is similar to Type I except the rate of incline of gas is slower and thus extended. The final type, IV, exhibits a conventional decline response. In this case, both gas and water are declining, typically at the same rate.

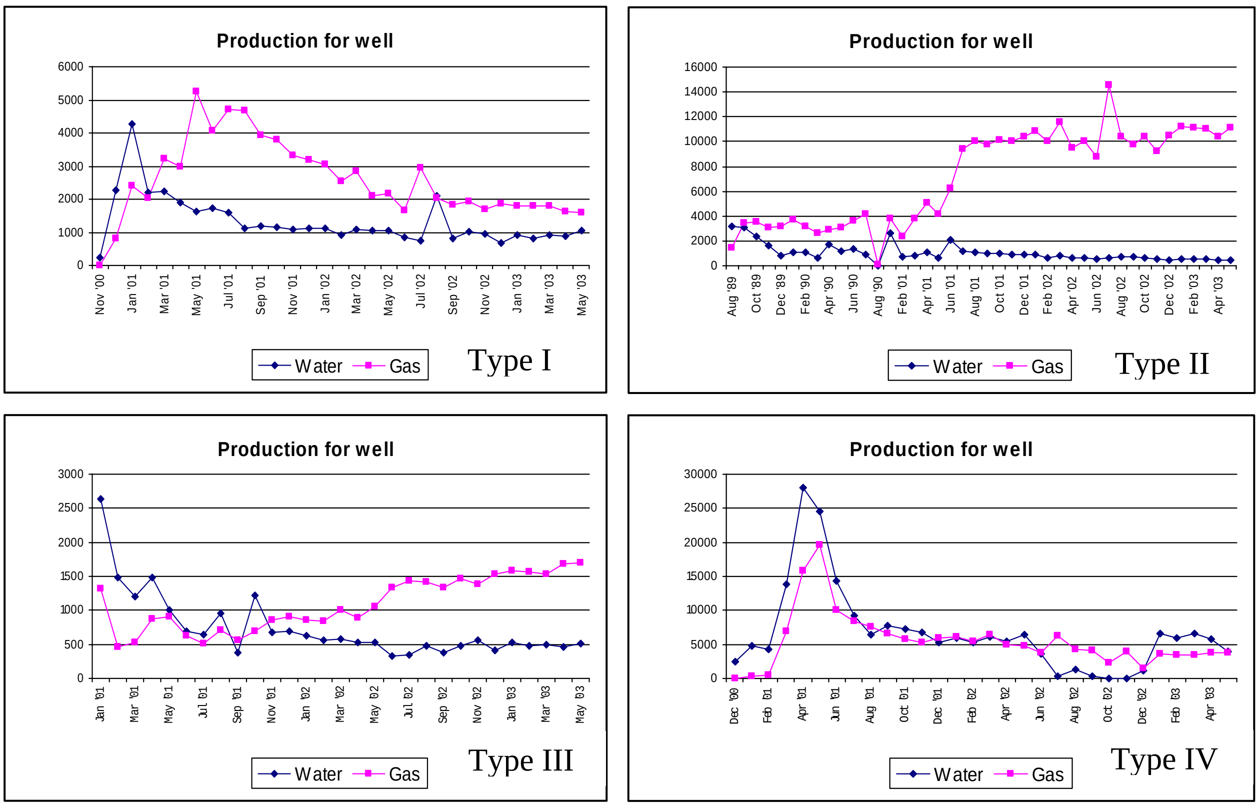


Figure 5.8 Various production behaviors for Raton Basin Wells

Since VPR B and D are adjacent to the Valle Vidal Unit, emphasis was on analyzing the production response from these wells.

VPR B: As mentioned previously, the majority of wells in VPR B produce from only the Vermejo Formation. Also, the average water-gas ratio for this region is low, 0.40, and therefore it is not a major water producer. However, on examining each well's performance, a maximum WGR of 2.9 was determined for a given well. Furthermore, the majority of wells in this region exhibit the type IV behavior described above, and these wells result in the highest WGRs. Figure 5.9 is a bar graph illustrating the frequency of each type for a given range of WGR.

Estimated ultimate recovery (EUR) for a well was determined using decline analysis of production rate vs. time. Notice, only Types I and IV display gas decline and therefore can be analyzed. On average, the EUR for Type I and IV wells is approximately 150 mmscf (million standard cubic feet) of gas. Types II and III are anticipated to have greater recovery.

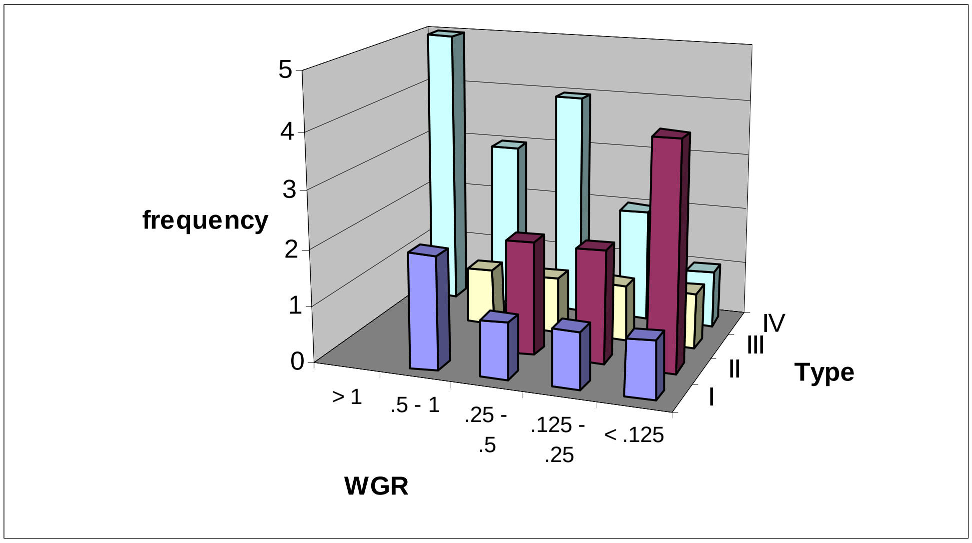


Figure 5.9 Frequency of the various production types for different WGR in VPR B.

VPR D: VPR D exhibits the lowest WGR of all the regions, and the highest percentage of wells completed only in the Vermejo Formation. Analysis of the various production curves resulted in the majority exhibiting either Type II or IV behavior. Furthermore, a subset of Type IV was identified and is labeled IV*. This subset follows the general conventional response as described for Type IV above; however the gas production is significantly greater than the water production. Figure 5.10 is an example illustrating this behavior.

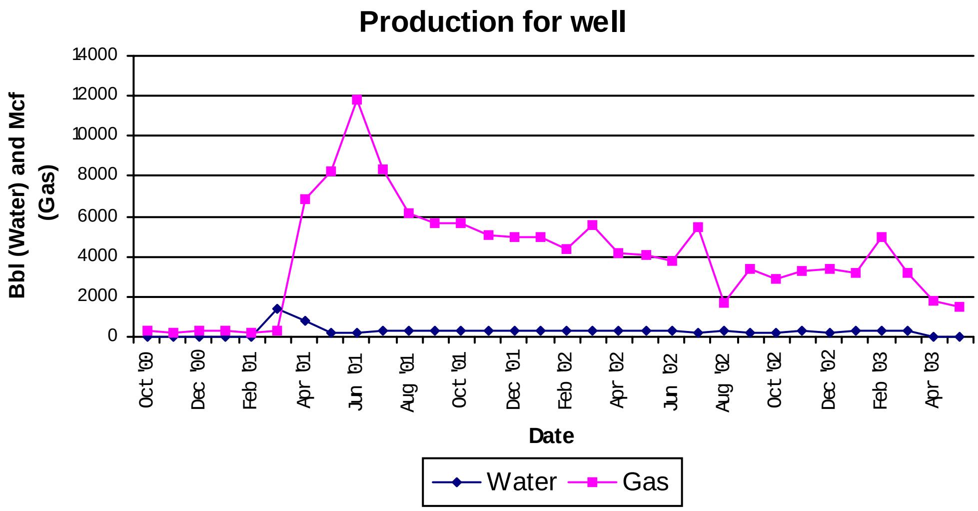


Figure 5.10 Example of Type IV* production behavior.

An investigation into the WGR for the various production types is shown in Figure 5.11. For the wells included in the figure, the overall WGR is low, especially for types II and IV*. However, the wells with the greatest WGR did not follow any of the identified production trends, but instead have inclining water behavior and therefore are not included in the figure. The ten wells exhibiting this behavior account for 25% of the total water production from VPR D. Eight of those occur immediately adjacent to the outcrop of the Vermejo Formation at the Vermejo Park Dome and may reflect the influence of direct aquifer recharge, but we have not data to confirm this possibility. Two are probably due to an erroneously high data anomaly in the public dataset available (we suspect data entry error or allocation error). EUR for VPR D wells is much better than VPR B, averaging 300 mmscf per well.

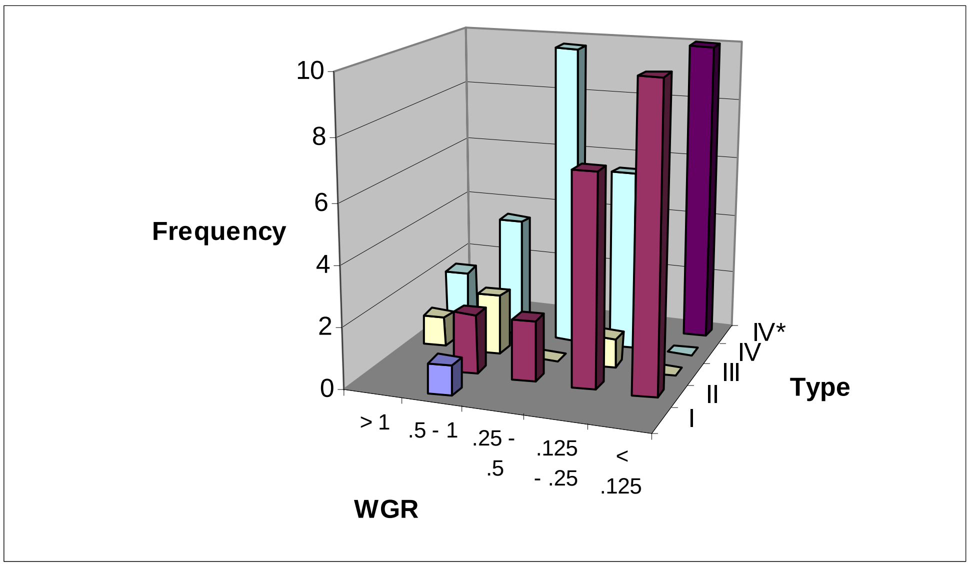


Figure 5.11 Frequency of the various production types for different WGR in VPR D.

5.3 Multi-well production response

A log-log plot of rate vs. time developed by Fetkovich (1980) provides the classic technique to identify if a well is in depletion mode; i.e., has achieved boundary dominated flow. Figure 5.12 illustrates the type curve generated for matching production data and determining reservoir and well parameters.

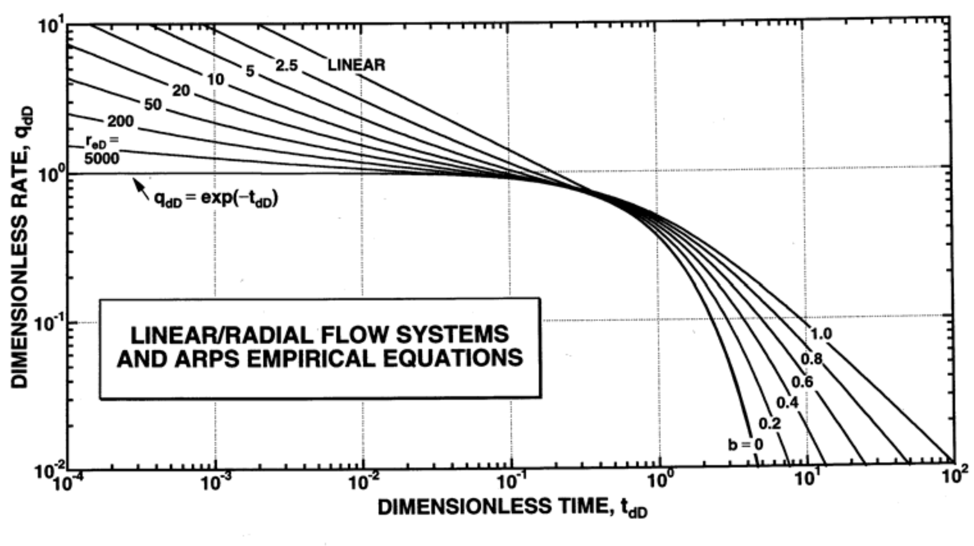


Figure 5.12 Log- log plot of rate vs. time (after Sunde et al., 2000)

The objective is to match production data to the depletion stem of the type curve and therefore be able to estimate drainage area. Due to the limited time these wells have been producing, (at best 30 to 33 months for leases B and D, respectively) no discernable match was achieved. Figure 5.13 is an example illustrating the transient response.

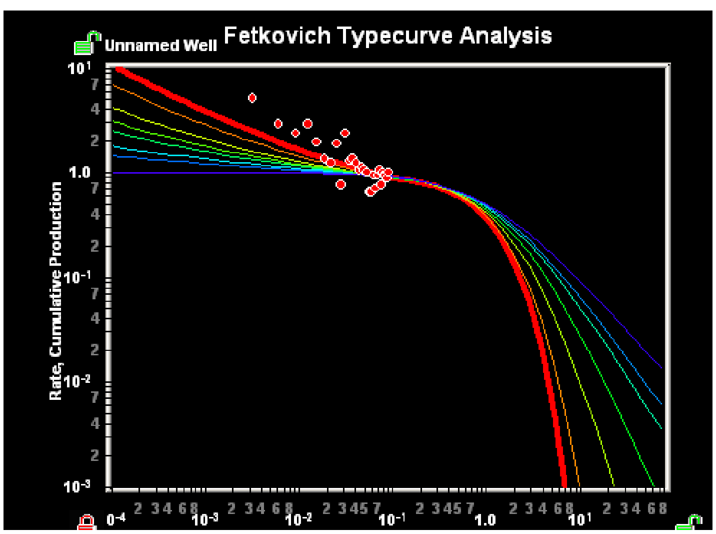


Figure 5.13 Example of a Raton Basin well illustrating limited data for matching.

5.4 Coalbed methane modeling

To interpret the production response a CBM model (Fekete, 2003) was applied to the data with observed CBM response. Input variables necessary for this analysis was taken from various sources (Close & Dutcher, 1990; Mavor et al., 1990; Stevens et al., 1992) and are listed in Table 5.3. No matrix shrinkage was included in this work.

Parameter	Parameter	Parameter
V_L = 450 scf/ton	P_L = 500 psi	P_{abnd} = 50 psi
P_i = 600 psi	GC = 250 scf/ton	k = 1-5 md
A = 160 acres	h = variable, ft	$C_p = 50x10^{-6}$ psi^{-1}
ρ_b = 1.75 gm/cc	T = 90-115 deg F	
ϕ = <2%	S_{wi} = 100 % (cleat)	

Table 5.3 Parameters for CBM model

The objective was to determine original gas-in-place for a generic coalbed methane well. Based on the above parameters, gas-in-place in VPR B and D is estimated to be 3 Bscf and 2.4 Bscf, respectively for a quarter section. This translates to 5 % to 12% recovery using the before-mentioned EURs for VPR B and D, respectively. To put this in perspective, the Potential Gas Committee in 2000 reports recoveries of 12% for the Fruitland Coal of San Juan Basin and 37% for the Raton and Vermejo Coals of the Raton Basin (including the Colorado portion). The VPR wells are relatively young in their production cycle and it will take several more years of production (at minimum) to be able to predict accurate EURs for these wells based on decline-curve analysis or modeling.

5.5 Summary

Development in the New Mexico portion of the Raton Basin is subdivided into five leases defined as VPR A, B, C, D, and E. Since VPR B and D are adjacent to the Valle Vidal Unit, emphasis was on analyzing the production response from these wells. Results indicate a reduced water-gas ratio (WGR) in VPR B and D with respect to the rest of the basin.

Production is commingled from numerous coal seams and sand lenses from both the Vermejo and Raton Formations. Production responses for individual wells were divided into four categories, several of which exhibit a coalbed methane type response. However, the most prevalent category exhibited conventional depletion behavior for water and gas in a low-permeability formation. This implies a contribution from the sandstones along with the coals.

Estimated ultimate recovery (EUR) was determined for only those wells that exhibited production decline. On average, these type of wells in VPR D are anticipated to recover 300 mmscf and in VPR B, approximately 150 mmscf, respectively. These recoveries are minimum values, and do not account for wells with no decline (Type II and III) or the possibility of a delayed coalbed methane response beyond the current production time. As can be seen, better recovery is anticipated in VPR D (by almost double) than in VPR B. Consequently, development in and adjacent to VPR D is more favorable. This does not mean that VPR B wells are subeconomic. Analysis could not determine a typical drainage area for wells in VPR B and D; therefore, results are inconclusive in support of or against the potential for 80-acre development. Key factors relevant to not obtaining drainage areas are: (1) the time dependency of the method to achieve a match for estimating drainage area. Production type curve matching requires sufficient data to achieve the depletion match and thus determine drainage volume. In this work, production has occurred for only 30 to 33 months, exhibiting only transient flow conditions and not sufficient time to determine depletion parameters. (2) aquifer support may mask depletion effects, and (3) desorption may mask or delay effects.